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14. ABSTRACT
Tactical teams need tools to support their collaboration and help coordinate their workflow. The HERMES solution consists of two major elements: 1) the SLATE spatial messaging collaboration tool and 2) a new concept called Workflow Coordinating Representations (WCRs) that supports task management and distributed workflow. SLATE imports mission documents, such as maps, images, and timelines, and allows users to share annotations on those documents. WCRs provide a communal representation of distributed group tasks, such as biometric analysis, where all operators can share information, and comment on the on-going activity. Phase II of the project consisted of a spiral process of design, development, evaluation, and transition. Along the way, empirical scientific tests of the design contributed to our theoretical understanding of small, distributed team collaboration and support technology.

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Phase II Base Final Report

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Contractor:	Pacific Science & Engineering Group, Inc. 9180 Brown Deer Road San Diego, CA 92121
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Abstract. Tactical teams need tools to support their collaboration and help coordinate their workflow. The HERMES solution consists of two major elements: 1) the SLATE spatial messaging collaboration tool and 2) a new concept called Workflow Coordinating Representations (WCRs) that supports task management and distributed workflow. SLATE imports mission documents, such as maps, images, and timelines, and allows users to share annotations on those documents. WCRs provide a communal representation of distributed group tasks, such as biometric analysis, where all operators can share information, and comment on the on-going activity. Phase II of the project consisted of a spiral process of design, development, evaluation, and transition. Along the way, empirical scientific tests of the design contributed to our theoretical understanding of small, distributed team collaboration and support technology.

Navy operations are increasingly composed of distributed assets that interact and collaborate over great distances. Not only must fielded assets coordinate information and actions among distributed team members, but they must increasingly coordinate their actions with reach-back assets that perform analysis and consultative functions. Maritime Interdiction Operations (MIOs) provide a good example. Fielded assets include one or more vessels, the boarding party, and local surveillance assets such as helicopters, airborne radar aircraft and uninhabited aerial vehicles. Reach-back assets include remote command authorities and analysis teams for video exploitation, chemical and biometric analysis, and others.

This distribution of tactical teams across space, and across time, imposes a number of collaboration requirements. Within MIO, the collaboration requirements include spatial representations of the vessel layout and other spatial information, communication management (especially for asynchronous communications and interruption recovery), task management for coordinating activities across distributed team members and reach-back assets, and pacing and security constraints on the head down time required to use collaboration technology.

The HERMES solution, named after the Greek messenger of the gods, is designed to support these requirements for distributed team collaboration and knowledge interoperability. The HERMES solution consists of two major elements: 1) the SLATE spatial messaging collaboration tool and 2) a new concept called Workflow Coordinating Representations (WCRs) that supports task management and distributed workflow. SLATE imports mission documents, such as maps, images, and timelines, and allows users to share annotations on those documents. Its design is grounded in cognitive science concepts of collaboration and knowledge interoperability, and it offers several important benefits including very low bandwidth for communicating among distributed teams, good team situation awareness, and effective collaboration support.

WCRs provide a communal representation of distributed group tasks, such as biometric analysis, where all operators can share information, and comment on the on-going activity. It explicitly supports collaboration by managing the data involved in the activity, presenting task status information, and providing a place for users to comment, critique, and review. It also explicitly supports task management activities such as who is responsible for an activity and making hand-offs of activities and data clear.

Phase II of the project consisted of a spiral process of design, development, evaluation, and transition. Along the way, empirical scientific tests of the design contributed to our theoretical understanding of small, distributed team collaboration and support technology. The phase II project consisted of the following tasks:

Task 1.0 – Design and develop an integrated chat tool.
Task 2.0 – Design and develop the first Workflow Coordinating Representation.
Task 3.0 – Design an empirical study to evaluate collaboration concepts embodied in HERMES.
Task 4.0 – Conduct field trials as part of the NPS-SOCOM exercises to evaluate usage of HERMES.
Task 5.0 – Develop an additional Workflow Coordinating Representation for an additional MIO activity.
Task 6.0 – Investigate transition opportunities.

US Navy experts from the vessel boarding training school at the Center for Security Forces (CSF), Learning Site, San Diego, from the Special Operations Command, and from the Naval Postgraduate School who have been briefed on the HERMES concept have been enthusiastic about its potential to support collaboration for MIO.

(Note: the software developed under the Hermes project is called SLATE. Below, the development of the SLATE software is described in the context of research and development as part and parcel of the Hermes project.)

Task 1: Chat tool. As part of the process of designing a chat tool for SLATE, we investigated the need for and design of a conversation threading capability for messages. We conducted a series of laboratory investigations to collect and analyze message sequences during a simple collaborative task involving two or three participants. Interleaved conversations were documented and analyzed. A threaded chat tool design was developed and implemented. In the developed design, users may send new messages or reply to any prior messages. On the interface, replies are collocated with the replied-to message and indented to indicate they are replies.

Task 2: Workflow Coordinating Representations. Tactical teams commonly use radios and chat to communicate. While chat at least provides a permanent record that can be reviewed asynchronously, neither chat nor radio can provide the rich content and context that the teams' coordination deserves (e.g. Cummings, 2004). To provide a richer medium for workflow coordination, we recently developed the concept of workflow coordinating representations (WCRs). WCRs are based on the concept of coordinating representations or devices (Alterman, & Garland, 2001) and boundary objects (e.g., Fischer et al., 2005). One common coordinating device is the use of the word "over" during radio communications to signal the end of a conversation turn. A WCR is a coordinating representation that displays a workflow in the shape of a communal form (St. John, 2011). Kirsh (2001) noted that "forms are another powerful coordinating mechanism in workplaces…they constrain the actions a user must consider," and they collate information into one place. Team members fill out the form as they conduct their tasks. Explicit locations for specific information can coordinate the organization and sharing of information for a set of experts since all are responsible for filling in their sections. The completion of one section by a team member signals task status and can be used to signal a hand-off of responsibility to another team member.

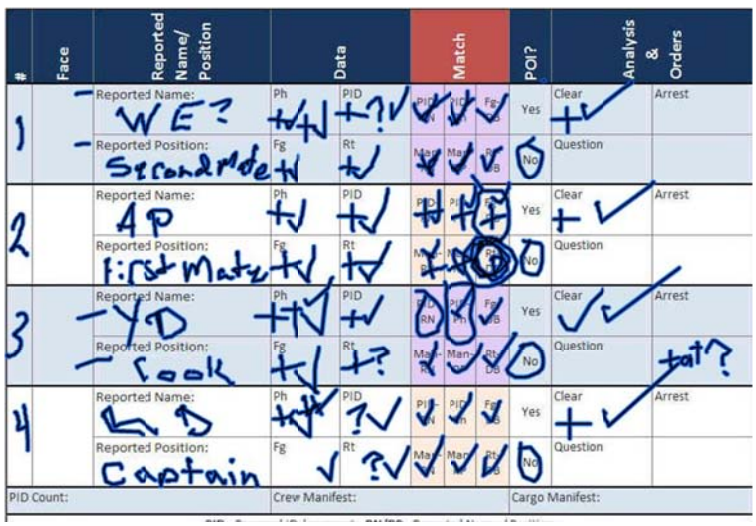
A WCR provides a common workspace and common ground (Clark & Brennan, 1991) for team communication and a venue for implicit coordination (Entin & Serfaty, 1999; Shah & Breazeal, 2010) since workflow is typically controlled by the state of the task rather than explicit commands. This common ground can include task information as well as collaboration information, such as task status and the current activities of team members (e.g. Carroll et al., 2003).

We developed and iteratively refined a WCR for coordinating the collection and exploitation of biometric data during maritime interdiction operations (MIOs). The process included in-depth interviews with subject matter experts, ecological interface design exercises, and iterative design with our design team. A series of laboratory studies of mock vessel boarding scenarios was conducted to evaluate successive designs.

During a MIO, a suspect vessel is searched by a boarding party. One task is to collect biometric data from all crew members and analyze it for persons of interest. In the near future, data will be uploaded to an analysis center, and results will be received immediately. This real-time process will require tight coordination among the boarding party and the analysis center to collect, transfer, and analyze the data, then comment, request additional data or clarifications, and recommend actions. Today's technology provides little workflow support for this task other than memorized checklists of the data that the boarding team is meant to collect. We developed a set of potentially useful WCR design properties to better support biometric data collection activities and then evaluated them in an empirical study. The study is described in the next section. The design properties were:

1. Mount the biometrics procedure checklist on a shared electronic whiteboard to allow all users to consult the list and annotate their progress and results. Research has documented the benefits of shared whiteboards for coordinating hospital teams (e.g. Bisantz, et al., 2010). Similar benefits should be obtained with MIO teams.
2. Display all task steps in the procedure, as with a checklist.
3. Iterate the checklist for each crew member in order to provide an explicit location on the WCR to check off and record each task step for each crew member. This design should telegraph the status of the task without the need for explicit progress reports.

4. Organize the procedure into a table with rows for crew members and columns to lay out the workflow from left to right. This design should make task status easy to observe. Alternatively, organize the WCR hierarchically with quadrants for task steps and crew members organized within each quadrant.
5. Provide a specific and detailed location for each piece of data and procedure, such as cross-checks and analysis results. To foreshadow the results, detailed locations invite more use of the WCR to document and comment on activities, rather than describing actions and data in chat. Greater use of the WCR is important because it builds the common ground among team members and organizes the data more effectively than if the data and comments are distributed among separate chat messages.
6. Provide a symbology and concept of use to convey common meanings and data and encourage interaction with the WCR. For the biometrics task, transmitting a data file was noted with a plus sign in the appropriate location. Confirming receipt of a file was noted with a check mark.
7. Collate all crew member data onto a single WCR in order to provide an integrated display for all interaction and rapid task status assessments. Alternatively, spread out each crew member's data onto separate WCRs to reduce the complexity of the form and provide more space for data and comments.



A biometric data collection WCR. The design uses a table organization with task steps in columns, crew members in rows, and detailed locations for each step (properties 1 - 7). The WCR is shown with annotations taken from the experiment.

As part of the WCR development process, we also identified and implemented a set of additional SLATE capabilities: 1) drag and drop text boxes onto SLATE canvases, 2) drag and drop symbols, and 3) drag and drop file transfer. All three capabilities were suggested by Navy experts during the Trident Warrior 2010 field experiment, described below.

The drag and drop text boxes allow users to drag a text box onto a canvas from a palette. Users can then type in the box. The benefit of text boxes is that users do not need to hand-draw text as an annotation. Instead, they can simply type. The result is much easier to create and then read text on a canvas.

The drag and drop symbols allow users to drag a number of different symbols onto a canvas from a palette. The specific symbols are pre-loaded for a specific mission or domain. They can include basic military symbols or more specific symbols related to a mission or domain.

For file transfer, image files (JPGs) can be dragged onto a canvas, where they can be loaded as new canvases or set as links from an existing canvas. This capability is useful for exchanging image files, such as fingerprints and photographs. It simplifies the process of exchanging files and uploading data collected by the field unit. It also makes SLATE a more integrated tool for collaboration and data organization. Dropping a file on a canvas leaves a mark. It can also leave a text label, if desired. Therefore, by dropping a file at a location on a WCR that is designed for a particular piece of data, the mark implicitly indicates the contents of the file as well as indicates that the specified data was transferred. For example, on the biometrics form, a user can drag a photo file onto the location specified for a photo of a particular crew member. The mark left by the drag and drop transfer indicates that the photo has been transferred, and the location of the mark indicates the contents of the file.

Additionally, we developed the ability to join and rejoin an existing mission. An important practical issue for SLATE demonstrations is how to recover from temporary connectivity outages. If infob messages are sent by other team members during an outage, how can they be recovered? The ability to rejoin a mission was added, so that users receive all of the interim messages when they reconnect.

A related issue is how a new user can join an on-going mission and receive all prior messages and canvases. When a user starts SLATE, it now checks to see if there are any on-going missions. If there are, it asks new users whether they wish to join. If they do, it downloads a complete and up to date copy of that mission.

We also investigated a pocket-size form factor for SLATE to increase its field usability. Ultimately, a smaller, pocket sized form factor could significantly increase SLATE's perceived viability and marketability. We investigated the capabilities of the new Samsung Galaxy Tablet, including its screen size and operating system. Because SLATE is written in FLEX, the SLATE code should port directly to the tablet, though some interface activities will have to be reimplemented for a touch screen. We began the reimplementation process by redesigning the user interface to fit on the smaller screen.

Task 3: Empirical study. An empirical laboratory study was conducted to evaluate properties for the design of an effective WCR for biometric data collection. In the experiment, five alternative designs with different sets of the properties, outlined above, were developed and evaluated empirically. Small teams of naïve participants used the alternative designs in a mock biometrics data collection task, and their usage and opinions about the utility of the alternatives were collected. Several significant results were obtained that speak the effectiveness of the various design properties. A report of the results was submitted to the Human Factors and Ergonomics conference (St. John & Lacson, 2011a).

In Task 5, below, the results and lessons learned were used to develop new WCRs to support 1) the "captain's interview" process during a vessel boarding, 2) and to support collaborative mission planning in a rescue planning task familiar to CKI performers. Both of these tasks are different from the biometrics task, therefore, they represented good test cases for generalizing the design properties gleaned from the experiment.

A second laboratory study was conducted to investigate the WCR developed for the collaborative mission planning task. The experiment materials from Biron, Burkman, & Warner (2008) were adopted. Two alternative versions of the WCR were developed to evaluate a) a design that conformed with the properties developed during the first study, and b) a design that violated those properties. The hypothesis was that the WCRs designed according to these guidelines would be preferred and would outperform the other design. The objective of this effort was to test the generality of the properties to different types of tasks.

The results indicated that the WCRs worked well for the well-established and proceduralized workflow of the biometrics tasks but poorly for the ad hoc brainstorming processes of the mission planning task. Like a checklist, the power of the WCRs seems to reside in their ability to externalize the structure and data for the well-known task and make the structure, data, and status available to the whole team to support hand-offs, coordination, and common ground. But this level of explicit structure does not seem well suited to ill-structured tasks like the give and take brainstorming required of mission planning. Chat, with its very light-weight interaction, seemed more appropriate for brainstorming rather than a WCR with its greater burden to lay out ideas in a specific format and level of detail.

The results from both studies were reported in the Human Factors and Ergonomics conference article (St. John & Lacson, 2011a). A more detailed version of the studies is reported in St. John & Lacson (2011b).

A separate manuscript was developed to discuss more generally the benefits of WCRs and whiteboards, such as SLATE (St. John, 2011). Additionally, the manuscript introduced a new hierarchical taxonomy of collaboration capabilities. Many interesting concepts and technologies have appeared in the research literature, yet it can be difficult to organize this literature, understand how different ideas relate to one another, and what combinations of capabilities might make for a comprehensive collaboration tool for a particular environment. A taxonomy of these collaboration concepts can help organize this research as well as offer a framework for comparing concepts, identifying capability gaps, and evaluating tools. A taxonomic framework can also contribute to a theory of collaboration by organizing capabilities into conceptual classes and explicitly calling out the structural relations among those classes.

Task 4: Field trials. SLATE was accepted for participation in the Trident Warrior 2010 Navy experiment as a laboratory-based technology (a special category for lower technical readiness level technologies). The materials developed for the laboratory study were adapted to this live exercise. In the exercise, two highly experienced Navy participants used SLATE to communicate and transfer files during a biometric data collection scenario. The WCR was well received by the experts, and they made important recommendations for improving it and better integrating it with the rest of their workflow and concept of operations. These recommendations were used to design and develop refinements and additional capabilities. A report of the findings was delivered to program management (St. John, 2010b).

The CENETIX group at the Naval Postgraduate School, led by Alex Bordetsky, also provides an excellent venue for field testing SLATE in MIO exercises and demonstrating SLATE to Navy users and customers. To support field trials, we integrated SLATE with the CENETIX software and developed a concept of operations for using the integrated package during a MIO exercise.

The integration consisted of two new SLATE capabilities. First, a SLATE user can send a SLATE text message to a CENETIX chat board in order to integrate communication among the systems. Second, a SLATE user can post an entire SLATE canvas, complete with annotations, to the CENTEX SA Viewer tool. This tool provides an interactive map. The SLATE canvas appears on the map at the location of the user who sent the canvas. This capability, for example, would allow a SLATE user to provide an efficient status update to a wide community of users not directly connected to SLATE. If the canvas contained the MIO WCR, for example, then the extended community could view the status of the biometrics data collection via the CENETIX SA Viewer. This conops allows team members to update outside users about the details of the mission and task status. This information can then be discussed in depth using the CENETIX collaboration tools, and new orders and data can then be channeled back to the team via the CENETIX software and SLATE.

Task 5: Additional WCR. An additional set of WCRs was developed to support the “Captain’s Interview” during a vessel search. Currently, the boarding officer has a list of over 30 questions to ask the vessel’s captain. The questions address everything from the ship’s registry to bills of lading and garbage logs. Not all questions are asked in each interview; much depends on the situation and prior answers. Our objective was to better organize the list and present it as a set of WCRs that could be used to 1) organize the questions, 2) provide a simple way to assess interview status, 3) provide a place for answers, and 4) provide a place for comments from remote team members, such as maritime domain awareness experts. The design of the interview WCRs followed the guidelines developed for the biometrics WCR. Our plan is to include both the biometrics WCR and the interview WCR in future NPS field exercises.

Task 6: Transition opportunities. A number of transition opportunities were investigated.

- Participated in the Navy Transition Assistance Program (TAP) in order to facilitate transition opportunities for SLATE.
- Investigated participation and demonstration at the Coalition Warrior Interoperability Demonstration (CWID) and the ThunderStorm exercise.
- Investigated the potential to integrate SLATE concepts into various enterprise-level systems, such as the Adobe Connect web conferencing system. Developed a preliminary version of the SLATE concept within the Adobe Connect Pro framework in order to verify feasibility.
- Investigated the potential to integrate SLATE concepts into the Enerdyne biometric wireless data collection system.
- Met with OPNAV N867 and the Biometric Fusion Center to learn more about current technology and conops. Developed an analysis of our market niche within this domain.
- Presented a key note address at the Offshore Patrol Vessel Summit in Norfolk, VA on May 26 as an opportunity to bring SLATE to relevant users’ attention.
- Shared the current version of the SLATE software with Dr. Norm Warner at NAVAIR, Dr. Sue Hutchins at NPS, Dr. Joan Rentsch at the University of Kentucky, and Dr. Emily Patterson at Ohio State University. Developed a short user’s manual to describe SLATE features.

- Additionally, pursued contacts at Primes, acquisition programs, and fellow researchers for transition and research opportunities. Contacts include Esri, Qualcomm, and Raytheon.
- Collaborated with Lisa Orloff at World Cares Center to investigate extending SLATE to the domain of humanitarian assistance. Executed a consultant contract with World Care to support this effort. This effort is the basis for the phase II option.
- Collaborated with Emily Patterson at Ohio State University to discuss applications of SLATE to emergency medical services (ambulance and emergency room collaboration). Developed a SLATE conops, mission, and specialized medical icons to demonstrate SLATE capabilities within this domain. Developed plans with Dr. Patterson to demonstrate the concept and apply for separate funding.

Recommendations. The SLATE collaboration software offers distinct advantages over commercial systems in terms of spatial information, team situation awareness, interruption recovery, coordinated activity, and ease of use. Much progress was made developing WCRs and their design properties to support nonspatial task procedures and team coordination.

The humanitarian assistance domain, which will be the focus of the Phase II Option, offers an excellent avenue for continued development of SLATE concepts and transition due to its need for small team coordination in a field setting. The development efforts in the MIO domain also offer good promise for transition within that domain.

Our recommendation is continued development within both the MIO and humanitarian assistance domains.

Deliverables:

St. John, M. F. (2011). A c*ollaboration taxonomy for tactical teams and two key implications*. Manuscript.

St. John, M. F. & Lacson, F. C. (2011a) An exploratory study of workflow support for tactical teams. Submitted to HFES.

St. John, M. F. & Lacson, F. C. (February 2011b). *Effective properties of a workflow coordinating representation for biometric data collection during maritime interdiction operations.* Technical report. San Diego, CA: Pacific Science & Engineering Group.

St. John, M. (August 2010a). *Hermes: Collaboration tools for distributed teams.* Brief. San Diego, CA: Pacific Science & Engineering Group.

St. John, M. F. (May, 2010b). *Trident Warrior 2010 – SLATE.2 – Collaboration software for distributed teams – Summary report.* Technical report. San Diego, CA: Pacific Science & Engineering Group.

St. John, M. & Dister, B. (2009). Wireless collaboration technology to support distributed teams. *Cognitive Technology, 14,* 4-13.

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